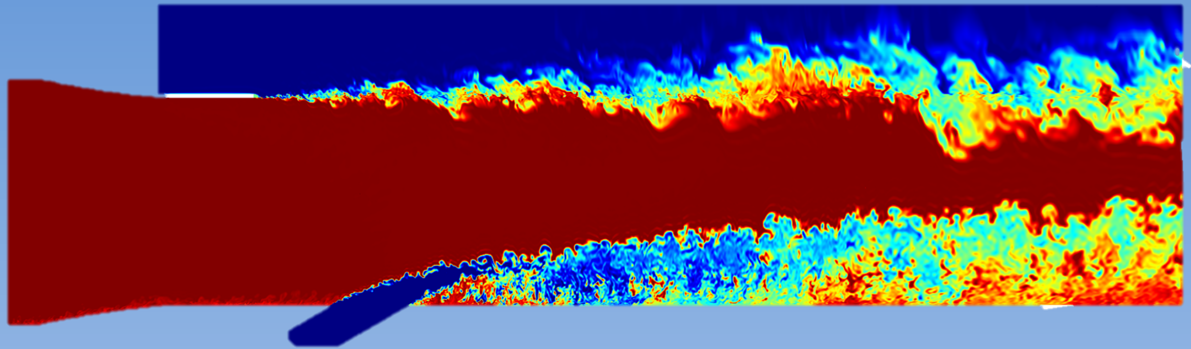
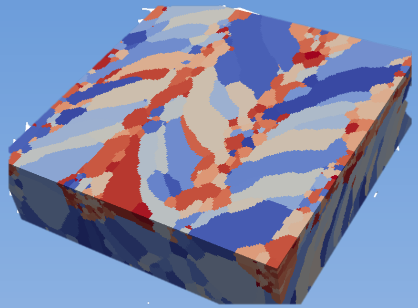
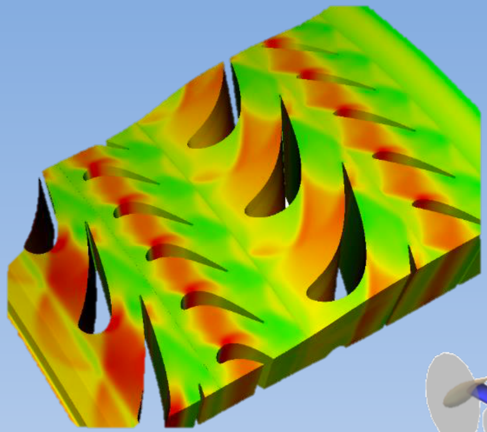
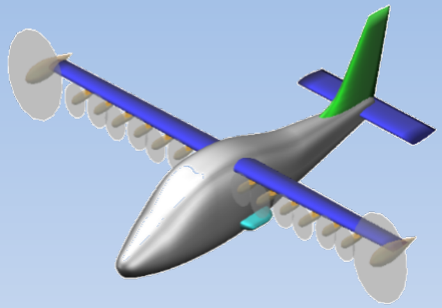
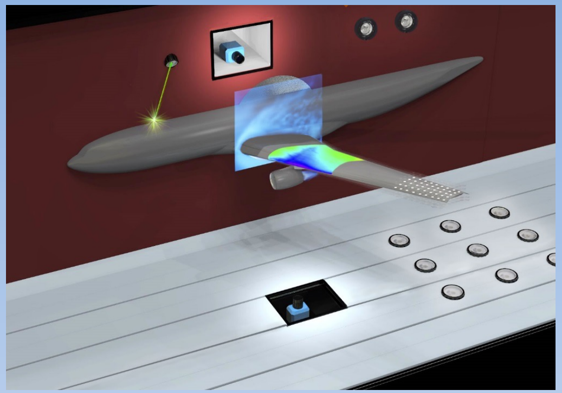
Transformational Tools and Technologies (T^3) Project



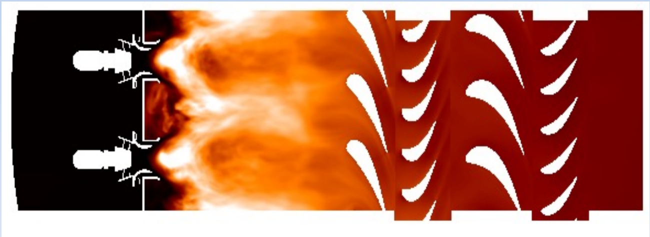








T^3 Project Overview
For RCA NRA Review
August 31, 2021



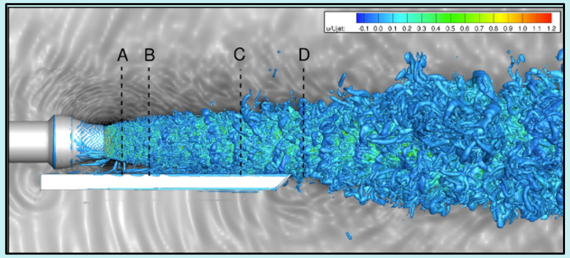
Michael M. Rogers, Project Manager
Dale Hopkins, Deputy Project Manager
Joe Morrison, Associate Project Manager

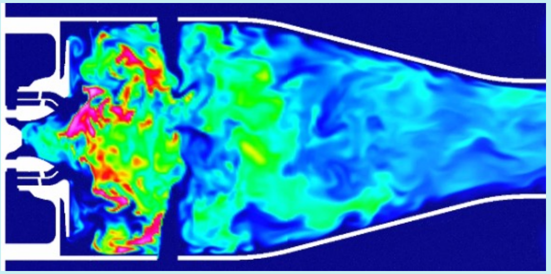
Host Center: Glenn **Partner Centers: Ames, Armstrong, Langley**

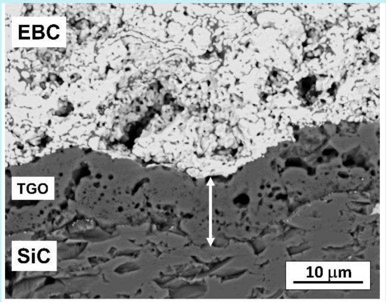
Transformational Tools & Technologies (T^3) Project

Enable fast, efficient design and analysis of advanced aviation systems from first principles and support exploratory research with breakthrough potential

- Perform foundational cross-cutting research for civil air vehicles across all six ARMD Thrusts
- Perform multidisciplinary system-level integration research in sub-projects focused on ARMD's stated priorities and sustain discipline-based expertise in important core capability areas
- Develop tools and technologies that support and enable the missions of other ARMD projects, U.S. industry, and other government agencies
- Develop transformational tools to promote new aircraft design and reduce development risk
- Develop and evaluate critical technologies to improve aircraft and test facility performance



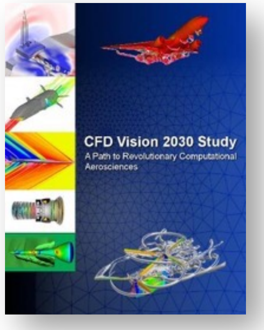
T^3 investment strategy is focused on delivering value to ARMD Mission Projects, Industry, and OGAs

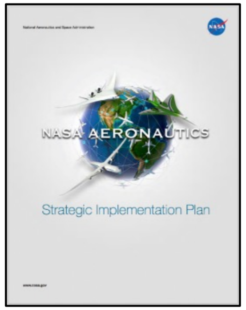
Continually Considering New Content & Fostering Innovation

T³ focuses on transformational cross-cutting foundational research

T³ supports all six ARMD Thrusts

Vision studies





AoA studies

ARMD Strategic Portfolio Management Review

Technical Community
(workshops, conferences, etc.)

Selection Criteria

- Foundational and Cross-cutting
- Potential Impact
- Supports Mission Projects
- Stakeholder Buy-in
- Transformational and Innovative
- Resource Constraints
  - Center/Competency balance
  - Labor/Procurement balance

Portfolio

Measures and Metrics

TACP Performance Metrics

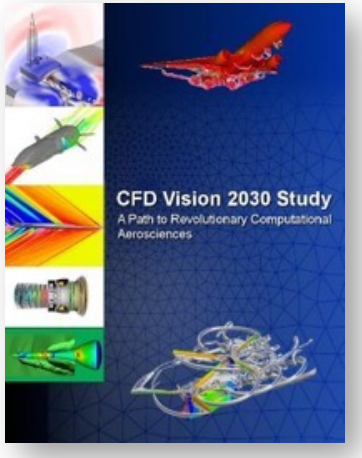
1. **ARMD Alignment**
2. **Agility**
3. **Innovative Culture**
4. **Transformation**
5. **Aviation Outcomes**

Encourage injection of new ideas, techniques, and approaches

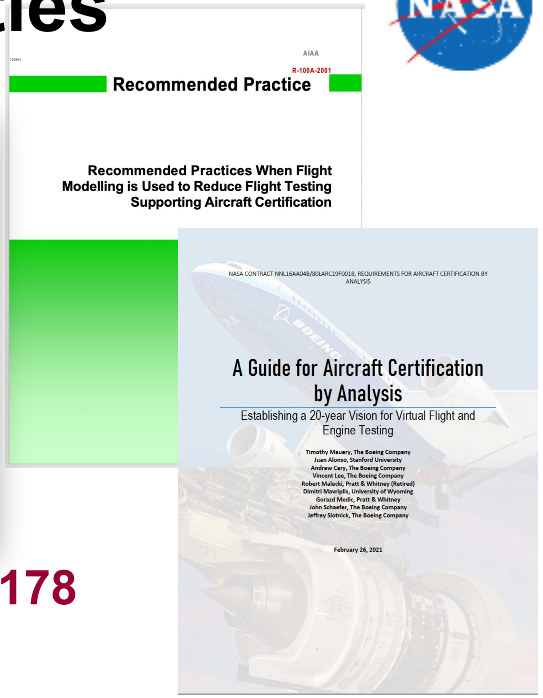
Community Vision Documents Informing T^3 Activities

CFD2030 – CFD Vision 2030 Study

- “Provides a knowledge-based forecast of the future computational capabilities required for turbulent, transitional, and reacting flow simulations”
- Vision funded by T^3, but enjoys broad community support and continued engagement (e.g. AIAA CFD Vision 2030 Integration Committee, AIAA Certification/Qualification by Analysis Community of Interest) - broad participation across industry, OGAs, and academia
- TCs in RCA, MDAO, and Combustion Modeling all aligned with vision strategic areas and roadmap



NASA CR 2014-218178

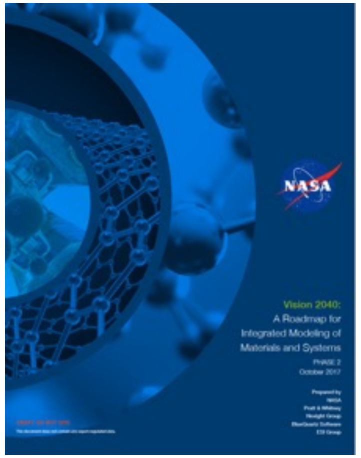


NASA CR 20210015404

A Guide for Aircraft Certification by Analysis – A 2040 Vision

M&S 2040 - A Roadmap for Integrated, Multiscale Modeling and Simulation of Materials and Systems

- Combines “design of the materials” (material scientist viewpoint) and “design with the materials” (structural analyst viewpoint) approaches into concurrent, model-based paradigm
- Provides for “concurrent design, development, and deployment of materials and systems throughout the product lifecycle for affordable, producible aerospace applications”
- More than 450 professionals participated in Vision development
- FY20 NRA solicitation to jumpstart foundational work in computational M&S



NASA CR 2018-219771

T3 FY21 Organizational Structure

Executive Team:
Project Manager – Michael Rogers (ARC)
Deputy Project Manager – Dale Hopkins (GRC)
Associate Project Manager – Joe Morrison (LaRC)

Resource & Project Support:
Business Lead: Laura Farrell (GRC)
Center Analysts: Cecelia Town (ARC), April Jungers (AFRC), Laura Farrell (GRC), Tracey Frisby (LaRC)
NRA Manager: Tracey Frisby (LaRC)
Scheduler: Joyce Moran (GRC)
Strategic Comm Specialist: Diana Fitzgerald (LaRC)
Project Support Analyst: Jeanie Feagan (GRC)

Project Center Liaisons:

ARC	Andrew Meade
AFRC	Steve Cumming
GRC	Azlin Biaggi-Labiosa
LaRC	Melissa Rivers

Enduring Discipline Research Areas
(with Technical Leads)

Dale Hopkins
Discipline Strategy Management

Materials and Structures (M&S)
Steve Arnold (GRC)

Combustion
Jeff Moder (GRC)
Kathy Tacina (GRC)

Controls
Dennis Culley (GRC)
Steve Riddick (LaRC)

Joe Morrison
Discipline Strategy Management

Revolutionary Computational Aerosciences (RCA)
Mujeeb Malik (LaRC)

Innovative Measurements (IM)
Tom Jones (LaRC)

Multidisciplinary Design, Analysis, and Optimization (MDAO)
Trish Glaab (LaRC)

Communications, Navigation & Surveillance (CNS)
Casey Bakula (GRC)

Autonomous Systems (AS)
- Human Machine Teaming
- Other enabling disciplines

Kelley Hashemi (ARC)

Sub-projects
(Aligned with ARMD Priorities)

Foundational Electrified Aircraft Propulsion
Azlin Biaggi-Labiosa
Sub-project Manager

M&S
MDAO
Controls

Revolutionary Aviation Mobility
Vanessa Aubuchon
Sub-project Manager

AS
MDAO
Controls
Comm/Cybersecurity

Reduced Life Cycle Cost
Melissa Rivers
Sub-project Manager

RCA
IM
M&S

Enabling Supersonic Transport
Azlin Biaggi-Labiosa
Sub-project Manager

Combustion
M&S

Reduced Life Cycle Cost (RLCC) Subproject Overview

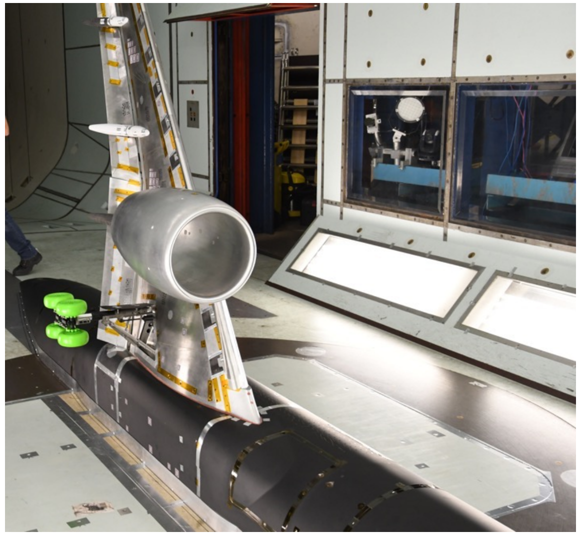
Phase 1: Research, Development, Test and Evaluation

Phase 2: Production

Phase 3: Operations & Maintenance

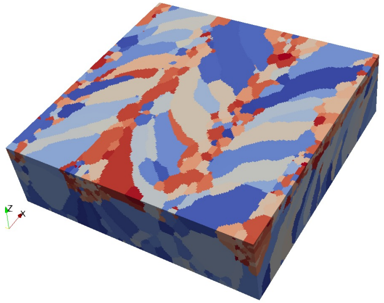
Phase 4: Disposal

Life Cycle of Aircraft



REDUCE THE TOTAL LIFE CYCLE COSTS BY:

1. **Enabling Certification by Analysis to reduce surprises during flight tests**
   - Develop and validate eddy resolving methods for airframe and propulsion system applications
   - Design and execute CFD validation experiments
   - Develop pressure & temperature sensitive paints to support dynamic measurements
   - Develop applicable velocimetry techniques for time-resolved unsteady flow



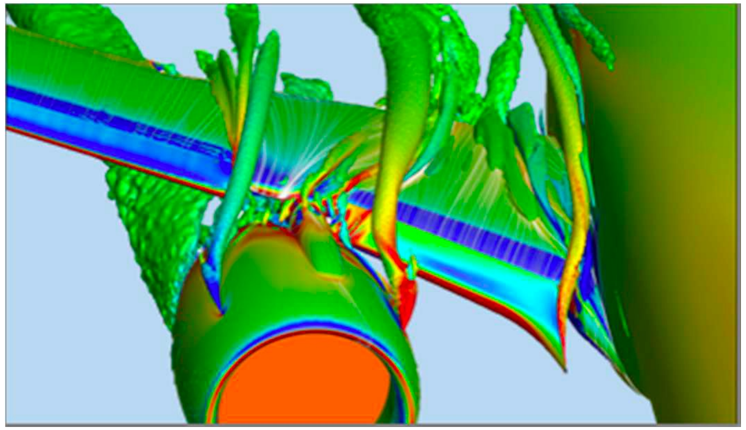
2. **Increasing manufacturing and assembly rates during the Production Phase**
   - Develop computational validation of additive and other advanced manufacturing processes
   - Advance rapid manufacturing of composite unitized structures

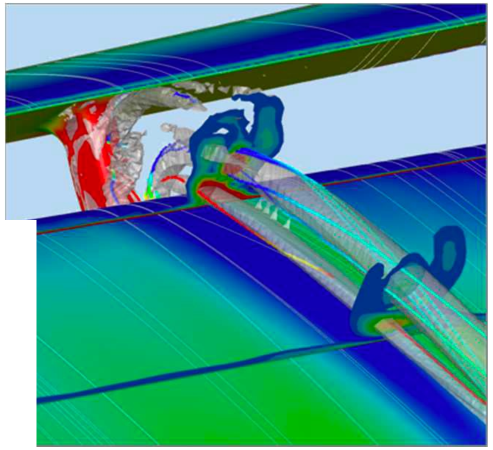
3. **FUTURE: Decreasing the amount of required maintenance during Operations and Maintenance Phase**
   - Enable predictive maintenance methods through advances in data fusion methods in the digital twin framework

Focus: Reduce the life cycle cost of aircraft to enable the US aircraft industry to stay competitive worldwide

How can new analytical tools reduce life cycle cost and decrease time to market for new products?

- **Increased use of computation for certification could save $100s millions for each aircraft development program by reducing flight test costs**
  - Two-thirds of flight test points are in the high-lift envelope
  - High-lift flow field is unsteady, geometrically complex, with interacting flow features
  - Accelerates improvements to the commercial aircraft fleet by enabling insertion of new technology/design changes without new flight tests
- **Improved computational tools enable novel vehicle designs for ARMD-focused missions (ultra-efficient commercial vehicles) and UAM**

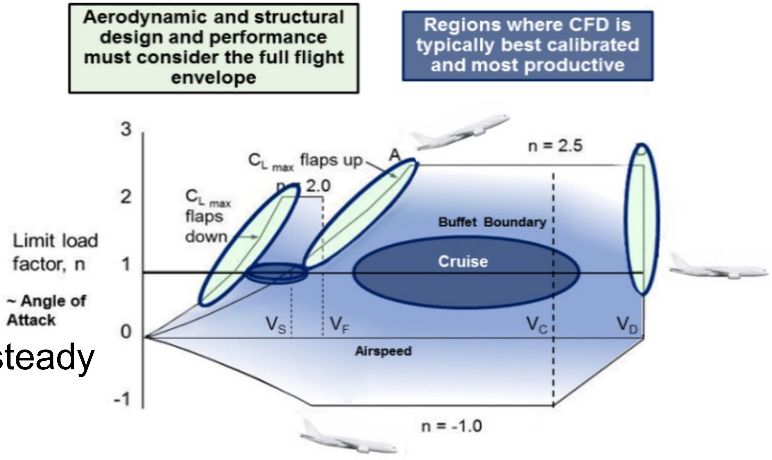




Technical Challenge: Develop and demonstrate computationally efficient, eddy-resolving modeling tools that predict maximum lift coefficient (CL*max*) for transport aircraft with the same accuracy as certification flight tests.

Technical Areas and Approaches

- **Physical Modeling and Simulations**
  - LES/WMLES, hybrid RANS/LES and Lattice-Boltzmann Method
  - Laminar-turbulent transition modeling
- **HPC Tools and Methods**
  - Effective utilization of emerging HPC hardware
  - Accurate, efficient, and robust computational methods
  - Reliable and effective grid generation and adaptation, including unsteady
- **CFD Validation Experiments**
  - Data to include flow separation and CRM high-lift

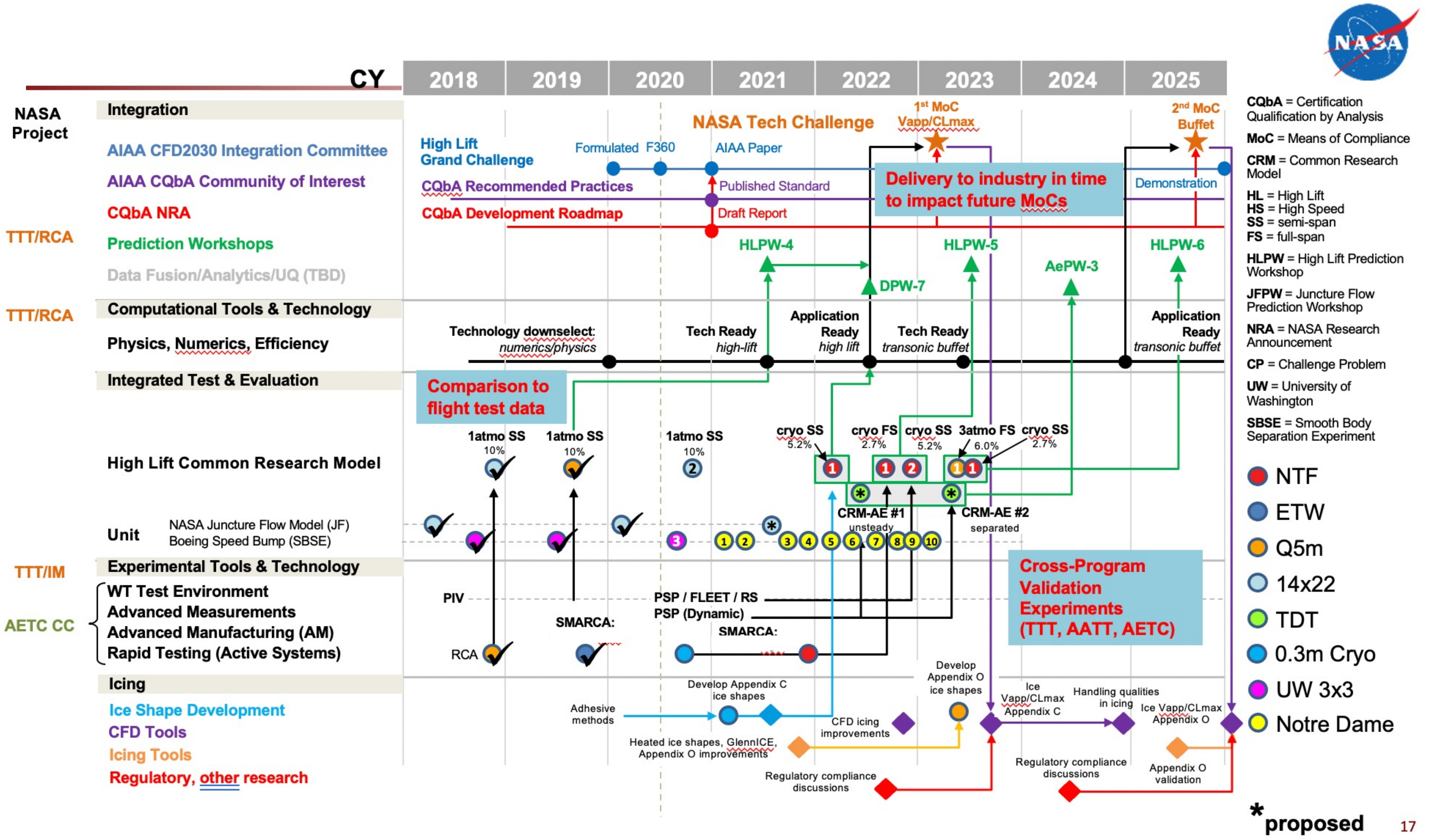


Opportunities for near-term impact of analytical tools to reduce certification time and cost

FSMBE / CQbA Integrated (NASA/Boeing/CFD Community) Roadmap

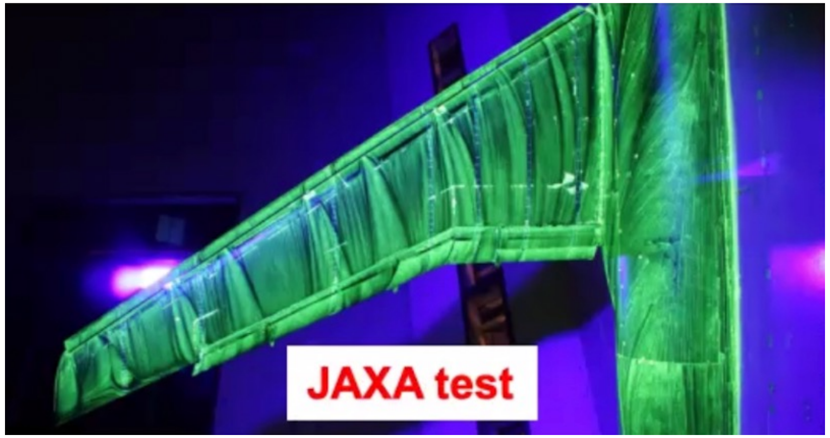
Partnering with Boeing and AETC

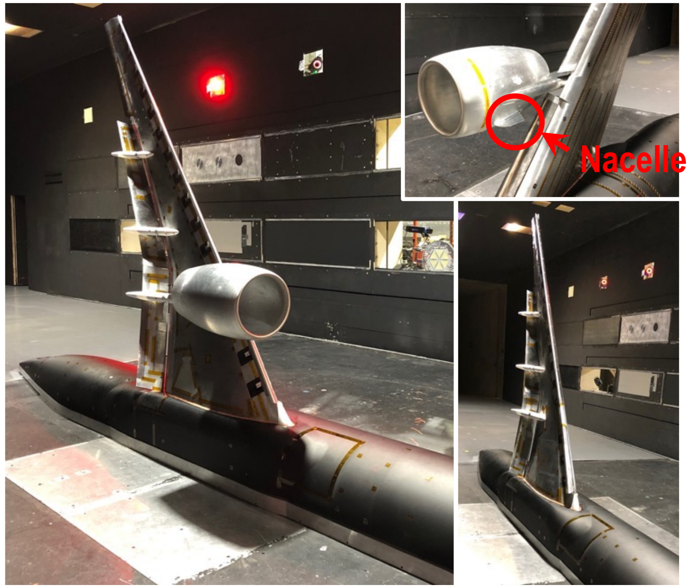
Series of wind tunnel tests and validation workshops



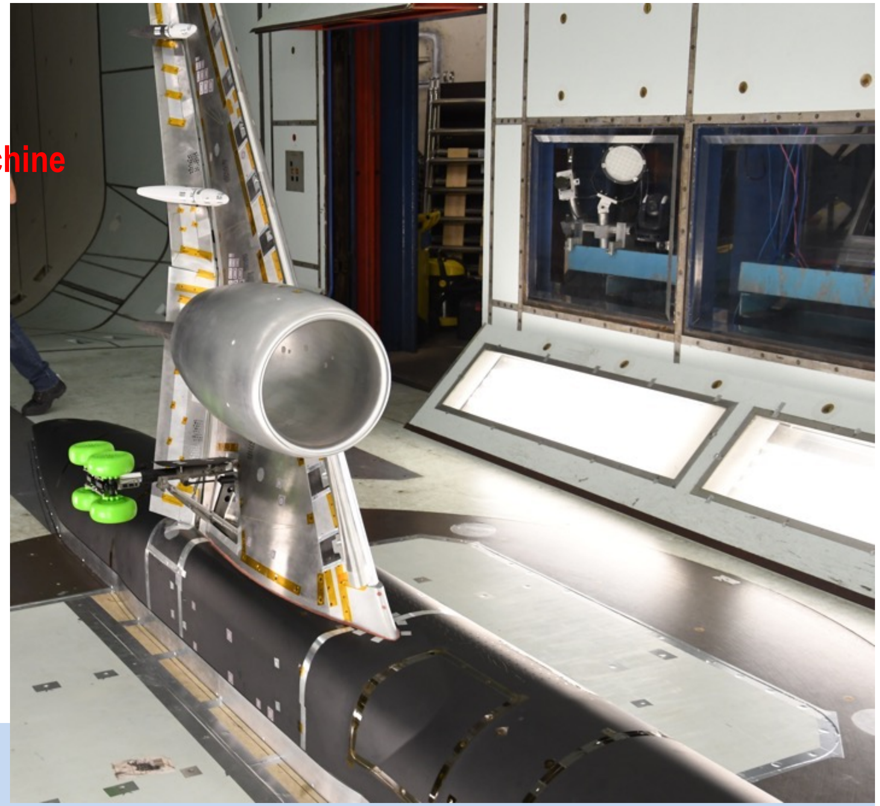
Deliver new computational tools in time to impact certification of future commercial transports

Validation Data for AIAA High-Lift Prediction Workshops





Semispan CRM-HL Test at LaRC 14'x22'
Oct-Dec 2018; model and test funded by AATT



Hi-Lift CRM test at Qinetiq 5m tunnel in UK Oct-Nov 2019

Eddy-resolving simulations (e.g. DES, WMLES)

- Do not predict spurious separation
- Give better lift near CL*max*
- Do not yield non-unique solutions
- Wall-Modeled LES CharLES code computations are capturing physics of flow separation (including pitching moment break) and explaining flight test results

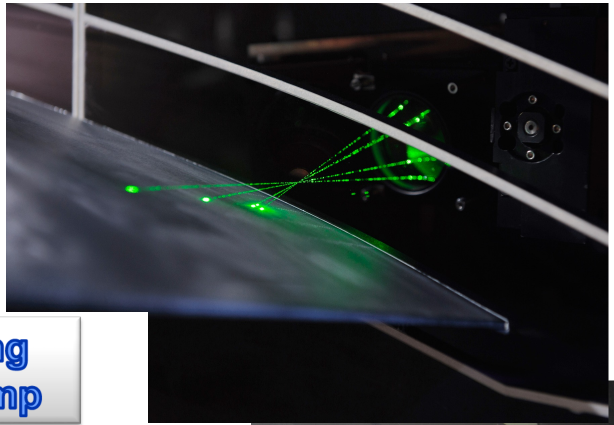
Development supported by T^3 NRA

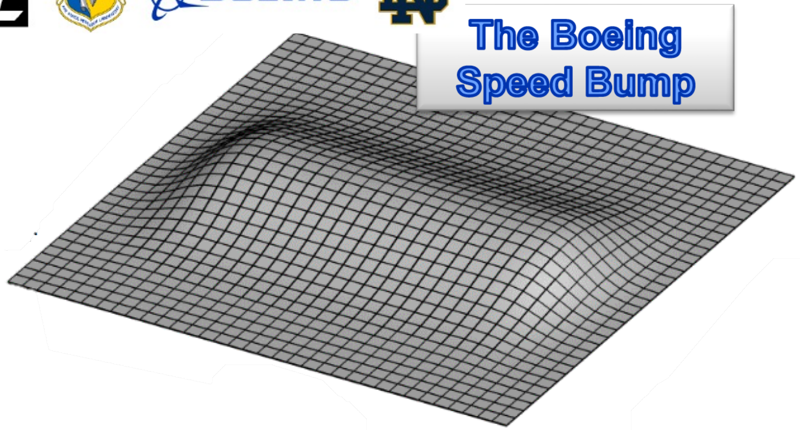
NASA CFD Validation Experiments

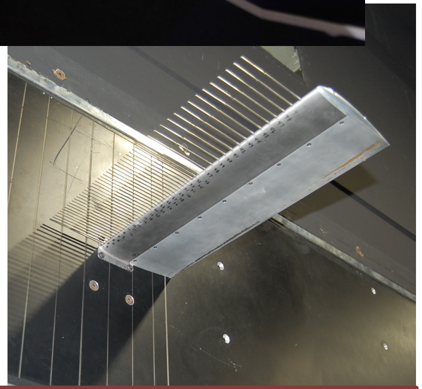
CFD Vision 2030 Recommendation 4. NASA should lead efforts to develop and execute integrated experimental testing and computational validation campaigns.

A CFD Validation Experiment should include the measurement of all information, including boundary conditions, geometry information, fluid properties, and quantification of experimental uncertainties necessary for a thorough and unambiguous comparison to CFD predictions.

- **Juncture Flow Experiment**
  - Prediction of wing trailing edge fuselage corner separation a challenge for CFD
  - Third 14’x22’ wind tunnel entry completed in Q1FY20
- **“2D” Separation**
  - NRA to Notre Dame (Flint and Corke)
  - “Boeing Speed Bump” ($1.8M/3 years)
- **Turbulent Heat Flux (THX) Experiment**
  - Need experimental data for CFD of turbulent heat transfer
- **Shock Wave/Boundary Layer Interaction**
  - Mach 2.5 Axisymmetric SBLI (attached and separated)
- **2D Compressible Mixing Layer**
  - NRA to U. Illinois (Dutton and Elliott)

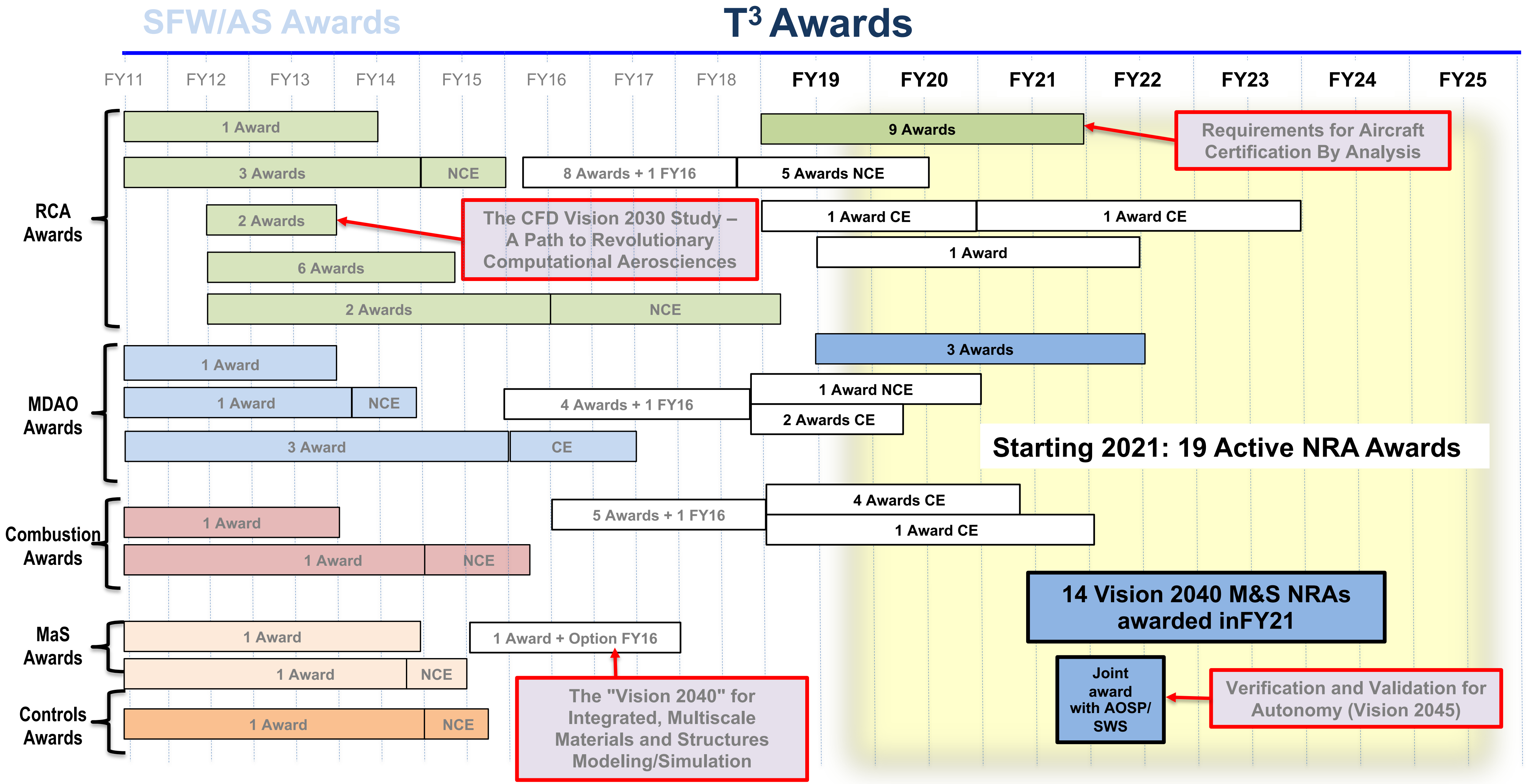






A new generation of CFD Validation Experiments is required to support model development of new eddy-resolving turbulence modeling approaches, which require a more complete description of the turbulence

NRAs: Collaboration with Universities to Assess Promising New Ideas Working with Industry/Community to Establish the Visions



A Look Ahead to FY22 and Beyond

- **Current subproject structure effective, but still investigating new content**
  - Considering additional new content in all subprojects and Enduring Disciplines
  - Considering possible new sub-project (e.g., “High-Speed”, “Net Zero Emissions”)
- **14 active new Materials & Structures NRAs supporting Vision 2040**
- **Winding down two Technical Challenges**
  - Combustion Modeling Technical Challenge completes at end of FY21 (on track)
  - MDAO Technical Challenge completes at end of FY22 (on track)
- **Formulating possible new Technical Challenges**
  - “Tools and Techniques Critical for m:N Operation of Autonomous Fleets”
  - Materials & Structures
- **V&V for Autonomy Vision 2045 effort underway**
- **Future Validation Experiments**
  - HiLift Common Research Model in the NTF (3 entries)
  - Aeroelasticity in the TDT (series of test)
  - Multidisciplinary propeller design assessment in the LSAWT
- **Complete definition of and assessment against new T^3 Measures and Metrics**